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Interim Report

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Executive Summary

The Weapon Systems Acquisition Reform Act of 2009 (WSARA) requires root cause analyses (RCA) be conducted for major defense acquisition programs (MDAPs) as part of the Nunn-McCurdy breach certification process. In 2010 and 2011, the Director, Performance Assessments and Root Cause Analyses (PARCA) conducted fourteen RCAs with the support of RCA reports by the Institute for Defense Analyses (IDA) and the RAND Corporation. The RCAs covered fifteen programs,[1] eleven MDAPs that had a critical Nunn-McCurdy breach and one MDAP and three major automated information systems (MAISs) that had severe cost growth issues.

Are most instances of extreme cost growth in MDAPs caused primarily by one or another of a few root causes—for example, incorporation of immature technologies, unrealistic cost estimates, inadequate program oversight? PARCA tasked IDA to investigate this question by examining the IDA and RAND RCAs it had sponsored and published.

Methodology

The IDA and RAND RCAs reported their findings at various levels of detail and in different terms. To assess the degree of commonality among the reported root causes, IDA had first to establish a taxonomy that would record and classify these root causes systematically.

The guidance in WSARA suggests eight possible root causes of cost growth:

1. Unrealistic performance expectations;
2. Unrealistic baseline estimates for cost or schedule;
3. Immature technologies or excessive manufacturing or integration risk;
4. Unanticipated design, engineering, manufacturing, or technology integration issues arising during program performance;
5. Changes in procurement quantities;
6. Inadequate program funding or funding instability;

[1] The Advanced Threat Infrared Countermeasures/Common Missile Warning System (ATIRCM/CMWS) RCA reported on the system's two subprograms, ATIRCM and CMWS, separately.

7. Poor performance by government or contractor personnel responsible for program management; or
8. Any other matters.

The RAND and IDA RCAs turned out to be much more complicated. Numerous findings were placed in the "Any other matters" category, and some causes with unique origins landed in the "Unrealistic baseline estimates" or "Poor performance by government or contractor personnel" categories; thus, the WSARA taxonomy lacked sufficient detail to capture the diversity of root causes.

In practice, PARCA grouped the root causes into three major categories—issues at program inception, issues during program execution, and exogenous factors—in their RCA reports. The distribution of root causes before and during program execution measures the balance of "birth defects" to "bad parenting" and indicates the extent to which there are opportunities for remediation within troubled programs.

This IDA report adopts PARCA's top-tier categories, discussed in the previous paragraph; retains, supplements, and modifies many of the issues identified one level down in the WSARA taxonomy as the "middle" tier; and lists the detailed root causes as even lower tiers to record the exact findings in IDA and RAND RCAs. This layout allows IDA to identify common issues among these RCAs. IDA's three-tier root causes taxonomy is provided in Table 2 and the detailed tabulation of the RCA findings is in Table A-1 in Appendix A.

Findings

The tables and figure in this Executive Summary present the results of IDA's assessment of the significant root causes of cost growth as reported in the RAND and IDA RCA reports at the top and middle tier levels only.

Root Cause Analyses Summary

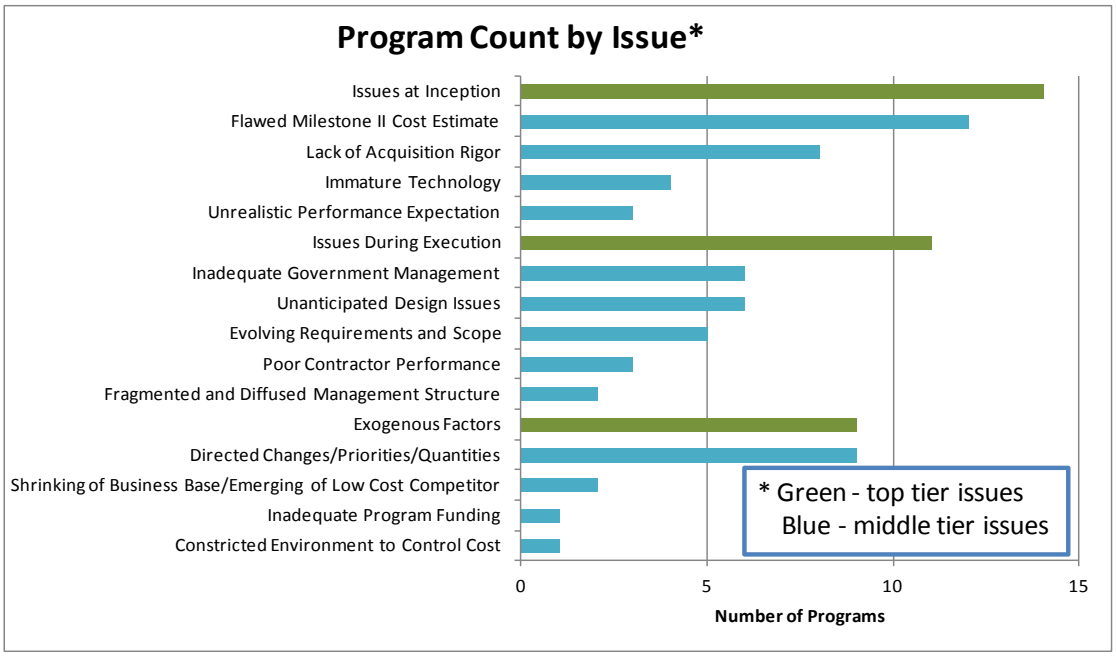
Causes of Cost and Schedule Growth	GCSS-MC	ECSS	Navy ERP	ACWA	ATIRCM	CMWS	Global Hawk	F35 (JSF)	RMS	FAB-T	Apache LB-BkIII	DDG 1000	WGS	Excalibur	JTRS GMR	Programs w/Issues
Issues at Inception	●	●		●	●	●	●	●	●	●	●	●	●	●	●	**14**
Unrealistic Performance Expectation					✓	✓									✓	3
Immature Technology					✓	✓					✓				✓	4
Lack of Acquisition Rigor	✓	✓		✓			✓	✓			✓	✓			✓	8
Flawed Milestone II Cost Estimate	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		12
Issues During Execution	●	●		●	●	●	●	●	●	●	●				●	**11**
Unanticipated Design Issues	✓				✓	✓	✓	✓			✓					6
Fragmented and Diffused Management Structure	✓	✓														2
Evolving Requirements and Scope	✓			✓			✓			✓					✓	5
Poor Contractor Performance	✓						✓			✓						3
Inadequate Government Management	✓			✓			✓	✓	✓	✓						6
Exogenous Factors				●			●		●	●	●	●	●	●	●	**9**
Directed Changes/Priorities/ Quantities				✓			✓		✓	✓	✓	✓	✓	✓	✓	9
Constricted Environment to Control Cost				✓												1
Shrinking Business Base/ Emerging Competitor													✓		✓	2
Inadequate Program Funding							✓									1

● Program has at least one mid-tier issue within the top tier

✓ Middle tier issue reported in IDA and RAND RCAs

At the top level (see the Program Count by Top and Middle Tier Issues figure below), root causes are spread relatively evenly between issues at inception, issues during execution, and exogenous factors. At the middle tier, flawed Milestone (MS) II[2] cost estimates (twelve programs), exogenous directed changes (nine programs), and lack of acquisition rigor (eight programs) during execution stand out from other general causes, with each of those containing more than half of the programs in the sample.[3] IDA grouped all instances where MS B decisions were made without rigorous deliberation on contract strategy, requirements, design maturity, acquisition plan, or cost estimate into the "lack of acquisition rigor" category. Twelve of the programs surveyed reported at least two of these prominent mid-tier causes; Global Hawk, CHEM-DEMIL ACWA, and Apache LB-Blk III reported all three causes. Evolving requirements and scope (five programs), inadequate government management (six programs) and unanticipated design issue (six programs) are middle tier issues cited for a third of these programs.

Program Count by Top and Middle Tier Issues



[2] MS II was the decision point to enter into Engineering & Manufacturing Development phase for programs initiated before 2000. DoDI 5000.2 issued on October 23, 2000 designated MS B as the entrance point into System Development and Demonstration phase, which was reversed back to Engineering and Manufacturing Development phase in DoDI 5000.2 of December 2, 2008. In this report, we use MS B and MS II interchangeably.

[3] Table A-1 in Appendix A provides a more detailed version of the above, and assigns mid- and low-tier causes to the fifteen programs.

Middle Tier Issue Counts by Program

	GCSS-MC	ECSS	Navy ERP	ACWA	ATIRCM	CMWS	Global Hawk	F35 (JSF)	RMS	FAB-T	Apache LB-BkIII	DDG 1000	WGS	Excalibur	JTRS GMR
Issues at Inception *	2	1		2	3	3	2	2	1	1	3	1	1	1	3
Issues During Execution Issues*	5	1		2	1	1	4	2	1	3	1				1
Exogenous Factors*				2			2		1	1	1	1	2	1	2
Total Issues	**7**	**2**	**0**	**6**	**4**	**4**	**8**	**4**	**3**	**5**	**5**	**2**	**3**	**2**	**6**
APUC Cost Growth % **				39%	282%	32%	23%	57%	55%	7%	31%	25%	27%	159%	45%
PAUC Cost Growth %**				43%	291%	25%	14%	57%	80%	25%	26%	86%	18%	211%	136%
Growth over MS A Estimate	641%	73%	28%												

* Top Tier issue reported in IDA and RAND RCAs

** Average Procurement Unit Cost (APUC) and Program Acquisition Unit Cost (PAUC) growths measured against program's current baseline

The number of specific root causes per program varies substantially across the sample of fifteen programs. Navy Enterprise Resource Planning (ERP) has no issues, DDG 1000 and Excalibur have two issues each, and Global Hawk has eight root causes responsible for its Nunn-McCurdy breach.[4] Interestingly, the number of root causes per program does not appear to be related to the degree of cost growth for that program. The two programs with the highest unit cost growth—ATIRCM and Excalibur—have four or fewer significant root causes of cost growth each, and the program with the greatest number of root causes—Global Hawk—has the smallest Program Acquisition Unit Cost (PAUC) and second smallest Average Procurement Unit Cost (APUC) growth of those surveyed.

Conclusion

IDA was commissioned to identify common root causes, if any, of cost growth across fifteen programs as reported in the RCAs by RAND and IDA. These programs experienced extreme cost growth and represent only a fraction of all MDAPs. Observations on these RCA reports should not be generalized. The RCAs reported many different root causes of cost growth for the programs. Some of the apparent differences could be attributed to the individual RCA selection process, or the choice of phrases to

[4] See Table A-1 in Appendix A for the assignment of lower-tier root causes to the fifteen programs.

describe the root cause. We expanded the root causes taxonomy to record the RCA findings as reported with no adjustment to account for their inherent subjectivity. Notwithstanding this limitation, five specific conclusions can be drawn from this exercise. First, the survey shows that the root causes of a program's cost growth are many. The reported root causes vary from program to program. Most programs have more than one significant root cause. These observations from the RCA reports stand in contrast to "single cause" theories, which attribute extreme cost growth across the MDAP portfolio primarily to a single factor such as immature technologies, inadequate systems engineering, or acquisition "culture" at DoD. Although some root causes—like unrealistic schedules, unanticipated design issues, quantity reductions—were common to several programs, none were present in more than two-thirds of the RCA reports. Furthermore, these factors were never the sole source of cost growth identified for the program in question. It is clear that the causes of extreme cost growth are many, not one.

Second, from the prevalence of causes of cost growth at program inception in the RCA reports, we can conclude that the rigor of the MS B process is important for controlling extreme cost growth. Fourteen of the fifteen RCA programs identified issues at inception as causes of cost growth. Unrealistic cost and schedule estimates, and flawed contract and contract incentive structures have been cited in several RCAs. Once embedded, issues at inception are difficult to overcome. A more rigorous and accountable MS B process would help to limit the incidence of "birth defects" that lead to extreme cost growth in MDAPs.

Third, exogenous factors often contribute to cases of extreme cost growth. Nearly two-thirds of the RCA reports (nine of fifteen programs) cited exogenous quantity reductions or requirements changes as responsible for cost growth. Directed quantity reduction drives up PAUC, and requirements changes and scope expansions lead to numerous contract modifications and increase the program acquisition cost. To the extent that these factors are truly exogenous to program initiation and execution, their influence on cost growth has the effect of exaggerating the severity of MDAP performance shortcomings in the data. Measures to control requirements growth and acknowledge the costs of directed changes could be implemented at program restructure to manage the influence of such exogenous factors.

Fourth, the RCA reports suggest that proper management of MDAPs is critical for controlling extreme cost growth. Roughly half (eight of fifteen programs) of the RCAs reported inadequate government oversight or ineffective contract management as significant causes of cost growth. Causes at program inception and exogenous factors can be unambiguously associated with given amounts of cost growth, and poor management and oversight issues act to exacerbate the consequences of cost growth, and the tie is difficult to quantify. Nevertheless, these execution issues are more important to be identified, because they are areas for improvement and remedial actions.

Finally, this exercise highlights the need for improved root cause taxonomy beyond that already suggested by WSARA and PARCA. Although the IDA research team proposed an alternative taxonomy, it did so by allowing the RCA reports, which used WSARA as a guide, to largely determine the structure beneath PARCA's top tier allocation of issues at inception, issues during execution, and exogenous factors. To improve the consistency, understanding, and usefulness of cross-program RCAs, more rigor is needed to structure future root cause taxonomies. A broader selection of programs and participants would serve well in future efforts towards this end. Along with improving the rigor of the MS B process, untangling the role of management performance, and acknowledging the influence of exogenous factors, the development of a cross-program RCA structure stands as a key opportunity for improvement.

Contents

A. Introduction

Between 2010 and 2011, the Director, Performance Assessments and Root Cause Analyses (PARCA) performed fourteen root cause analyses (RCA) for fifteen programs[1] that had severe cost growth issues. Pursuant to conducting these RCAs, PARCA commissioned independent reports from the Institute for Defense Analyses (IDA) and the RAND Corporation, examining the root causes of these programs' cost growth.

Are most instances of extreme cost growth in major defense acquisition programs (MDAPs) caused primarily by one or another of a few root causes—for example, incorporation of immature technologies, unrealistic cost estimates, and inadequate program oversight? PARCA tasked IDA to investigate this question by examining the IDA and RAND RCAs that had been sponsored and published.

B. Identification of the Programs Examined

This report covers the results of eight IDA and seven RAND RCAs (Table 1). The list contains fifteen reports for PARCA's fourteen RCAs, because IDA and RAND were both asked to perform an RCA on the Joint Strike Fighter program, F-35, independent of each other. The programs included in this report consist of ten MDAPs that experienced a critical Nunn-McCurdy breach between 2010 and 2011 and one MDAP and three major automated information systems (MAISs) that had significant cost growth issues. One MDAP RCA (ATIRCM/CMWS (Advanced Threat Infrared Counter Measure/Common Missile Warning System)) consisted of two subprograms; therefore, this analysis compares the root causes for cost growth on fifteen programs in total.

The programs in this report are a small fraction of the Department of Defense (DoD)'s acquisition portfolio; they are, however, a reasonable cross-section of the programs. The programs are distributed evenly across the Services with three programs each from the Army and the Navy, four from the Air Force, one from the Marine Corps, and three joint programs. Furthermore, they present a variety of system types, including ships, satellites, tactical fighters, electronics, and MAISs. This diversity of programs affords IDA the opportunity to assess the degree of commonality in factors contributing to critical cost growth across a wide spectrum of defense programs. However, due to the fact that each program has experienced or nearly experienced a critical Nunn-McCurdy breach, lessons drawn from the RCAs may only be applicable to other cases of extreme cost growth and may not be generalized to the broader MDAP portfolio, in which similar cost growth is not always present.

[1] The ATIRCM/CMWS RCA reported two subprograms, ATIRCM and CMWS, separately. Hence these fourteen PARCA RCAs were performed for fifteen programs.

Table 1. PARCA RCAs

Program	Analysis	Source
GCSS-MC*	*Global Combat Support System – Marine Corps: Root Cause Analysis (2012)*	IDA
ECSS*	*Expeditionary Combat Support System: Root Cause Analysis (2011)*	IDA
Navy ERP*	*Root Cause Analysis Serial #2: Navy ERP, Excalibur, Root Cause Analyses Methodology and Data Sources (2011)*	RAND
CHEM-DEMIL ACWA	*Chemical Demilitarization – Advanced Chemical Weapons Alternatives: Root Cause Analysis (2011)*	IDA
ATIRCM-CMWS	*Root Cause Analysis for the ATIRCM/CMWS Program (2010)*	IDA
Global Hawk	*Global Hawk: Root Cause Analysis of Projected Unit Cost Growth (2011)*	IDA
F-35	*WSARA 2009: Joint Strike Fighter Root Cause Analysis (2010); Root Cause Analysis of Nunn-McCurdy Breaches, Volume 1: Zumwalt Class Destroyer, Joint Strike Fighter, Longbow Apache and Wideband Global Satellite (2011)*	IDA; RAND
RMS	*Remote Minehunting System: Root Cause Analysis (2010)*	IDA
FAB-T	*Root Cause Analysis of Family of Beyond Line-of-Sight Terminals(2012)*	IDA
Apache Block III	*Root Cause Analysis of Nunn-McCurdy Breaches, Volume 1: Zumwalt Class Destroyer, Joint Strike Fighter, Longbow Apache and Wideband Global Satellite (2011)*	RAND
DDG 1000	*Root Cause Analysis of Nunn-McCurdy Breaches, Volume 1: Zumwalt Class Destroyer, Joint Strike Fighter, Longbow Apache and Wideband Global Satellite (2011)*	RAND
WGS	*Root Cause Analysis of Nunn-McCurdy Breaches, Volume 1: Zumwalt Class Destroyer, Joint Strike Fighter, Longbow Apache and Wideband Global Satellite (2011)*	RAND
Excalibur	*Root Cause Analysis Serial #2: Navy ERP, Excalibur, Root Cause Analyses Methodology and Data Sources (2011)*	RAND
JTRS GMR	*Root Cause Analysis: Joint Tactical Radio Systems Ground Mobile Radar (2011)*	RAND

*Growth as reported by GAO. PAUC/APUC growth not applicable for ERP acquisitions.

C. Methodology

To assess the degree of commonality among root causes of cost growth, IDA first reviewed these fifteen RCA reports, performed by IDA and RAND, and then selected an appropriate taxonomy for these RCAs in order to document and score the findings systematically. IDA chose to use the taxonomy in Table 2, instead of the root cause classification listed in the Weapon Systems Acquisition Reform Act (WSARA), to replicate the exact findings reported in the IDA and RAND RCAs.

Table 2. IDA Root Causes Taxonomy

1.0 Issues at Inception		
	1.1	Unrealistic Performance Expectation
	1.2	Immature Technology
	1.3	Lack of Acquisition Rigor[a]
		1.3.1 Flawed Contracting Strategy/Structure/Incentive
		1.3.2 Flawed Engineering Strategy
		1.3.3 Immature Design
		1.3.4 Adopted Unrealistic Cost Estimate
		1.3.5 Ambitious Requirement
	1.4	Flawed MS II Estimate
		1.4.1 Unrealistic Schedule
		1.4.2 Unrecognized Technology Requirement/Complexity
		1.4.3 Erroneous Cost Estimate
		1.4.4 Unrealistic Cost Estimate
		1.4.5 Flawed Weight Estimate
		1.4.6 Flawed Programmatic Assumptions
		1.4.7 Inadequate Risk Allowances
2.0 Issues during Execution		
	2.1	Unanticipated Design Issues
	2.2	Fragmented and Diffused Management Structure
	2.3	Evolving Requirements and Scope
	2.4	Poor Contractor Performance
		2.4.1 Scheduled Delivery/Defect Rate/Reliability
		2.4.2 Poor Management of Subcontractor
	2.5	Inadequate Government Management
		2.5.1 Inadequate Oversight/Situation Awareness
		2.5.2 Deficient Management/Funding Practice
		2.5.3 Poor Schedule Management
		2.5.4 Ineffective Management of Contractor Incentives
3.0 Exogenous Factors		
	3.1	Directed Changes/Priorities/Quantities
	3.2	Constricted Environment to Control Cost[b]
	3.3	Shrinking of Business Base/Emerging of Low Cost Competitor
	3.4	Inadequate Program Funding

[a] IDA grouped all instances where Milestone B decision was made without rigorous deliberation on contract strategy, requirements, design maturity, acquisition plan, or cost estimate into the category "lack of acquisition rigor."

[b] Regulations, international treaties and other considerations that constrict cost control measures.

WSARA postulated that the root causes of cost growth could be attributed to one of the following factors:

1. Unrealistic performance expectations;
2. Unrealistic baseline estimates for cost or schedule;

3. Immature technologies or excessive manufacturing or integration risk;
4. Unanticipated design, engineering, manufacturing, or technology integration issues arising during program performance;
5. Changes in procurement quantities;
6. Inadequate program funding or funding instability;
7. Poor performance by government or contractor personnel responsible for program management; or
8. Any other matters.

While the WSARA taxonomy has been recommended to guide RCAs, the RAND and IDA RCA research presented a more complex picture of the factors contributing to cost growth. Numerous findings were placed in the "Any other matters" category, and some causes with unique origins landed in the "Unrealistic baseline estimates" or "Poor performance by government or contractor personnel" categories; thus, the WSARA taxonomy lacked sufficient detail to capture the diversity of root causes. Without a conceptual backbone, the WSARA taxonomy has somewhat limited utility to the government in understanding, remedying, or preventing recurrent cost growth.

In practice, PARCA has followed a more structured format in their RCA reports. They grouped the root causes into three major categories: issues at program inception, issues during program execution, and exogenous factors. PARCA then reported root causes in greater detail within each group.

This IDA report adopts PARCA's top-tier categories, discussed in the previous paragraph; retains, supplements, and modifies many of the issues identified one level down in the WSARA taxonomy as the "middle" tier; and extends the structure further by adding lower-tier issues to replicate the exact findings in the IDA and RAND RCAs. Related lower-tier causes are then grouped under an overarching mid-tier cause. For example, WSARA's root cause "Unrealistic baseline estimates for cost or schedule" is modified to the mid-tier cause "Flawed Milestone (MS) II Cost Estimate," which includes "Unrealistic Schedule," "Erroneous Cost Estimate," "Unrealistic Cost Estimate," and other root causes identified by IDA and RAND. Mid-tier causes without any lower-tier causes are themselves root causes. From the IDA and RAND RCAs in Table 1, IDA derived the structured taxonomy on root causes to classify RCA findings in Table 2.

Issues at program inception can be thought of as a program's "birth defects" and include such factors as unrealistic cost or schedule estimates, immature technology, unrealistic performance expectations, poorly defined requirements or scope, and lack of acquisition rigor. These are sources of cost growth inherent in the Acquisition Program Baseline (APB). Although the consequences of these birth defects may not emerge until program execution, DoD managers have limited leverage to remedy issues at inception

once incorporated into a program's baseline or acquisition strategy. The recognition of common issues at inception is valuable to guide the post-Nunn-McCurdy restructuring process and to apply lessons learned from flawed program initiations to new acquisitions.

Issues during program execution can be thought of as "bad parenting" during the development (or production) phase of a program. Issues during execution include unanticipated design difficulties, poorly functioning management structures, inadequate government management, and poor contractor performance after program initiation. By definition, these problems cannot be traced back to flaws in the original program plans or estimates, and they signal management or performance shortcomings above and beyond those typical for similar programs. Unlike issues at program inception, execution difficulties may be remedied midstream. Heightened oversight, streamlined management structures, or more effective contract incentives, for example, have the potential to stabilize cost growth for a program suffering from execution issues following (or in anticipation of) a Nunn-McCurdy breach. Knowledge of common issues during execution affords DoD and PARCA opportunities for intervention in troubled programs to control cost growth.

Directed changes in quantity or requirements; changes in political or funding priorities, regulations, treaty requirements, and others that constrict cost control measures; or shifts in the industrial base constitute a third category of exogenous factors contributing to cost growth. To the extent that these factors are truly external to the program—quantity reductions prompted by cost overruns and scope additions correcting incomplete requirements do not meet this standard—exogenous factors and their resultant cost overruns must be considered unavoidable. The three basic categories in IDA's taxonomy—issues at inception, issues during execution, and exogenous factors—and their constituent causal variants therein identify the character and locus of root cause within a program's life cycle and management chain. These higher levels of the taxonomy are roughly consistent with PARCA's current classification structure, which facilitates greater understanding, remediation, and prevention of common causes of cost growth than the original WSARA taxonomy. When combined, the PARCA classification structure and WSARA taxonomy compose the first two tiers of the proposed classification structure. When assessing the incidence of root causes across programs, these top two tiers constitute the primary level at which common causes should be measured.

Beneath the top two tiers of the taxonomy lies a more detailed classification of the specific causes of cost growth for the fifteen programs that IDA examined. These sub-categories in the third tier, which are listed in Table 2, correspond to root causes of cost growth documented in the IDA and RAND RCA reports. Because the survey covers a diverse selection of programs, the makeup of this lower tier was determined primarily by the reports themselves in order to give a more detailed perspective rooted in the unique

program cost growth histories. This process explains why many of the sub-categories apply to only one program. Accordingly, causal commonality is less likely to arise from the lower tier, but when it does, commonality may be indicative of specific, recurring problems across programs that deserve heightened scrutiny.

Many of the programs in the survey had multiple causes of cost growth. In such cases, the set of causes was first narrowed to those factors judged to be significant contributors to cost overruns. Even where the RCAs quantitatively apportioned cost growth among several significant causes, no attempt was made to discriminate more finely among those significant root causes.[2]

The individual RCA reports reported root causes at various levels of detail and in different terms. For example, one report reported poor government performance as the root cause, while another elaborated on the lack of oversight, ineffective management of contractor incentives, and poor schedule management. Some reports identified an unrealistic cost or schedule estimate as a root cause, while others pointed to unrealistic schedule, erroneous estimate, or flawed weight estimate as the issues. At the lowest level, RCA-identified causes determined, with a minor degree of standardization on terminology, the sub-categories of cost growth. This allowed IDA to align a reported root cause to a sub-category closest to its description. Related sub-categories were then consolidated into mid-level issues in the proposed causal taxonomy, and then into the three top-tier groups: issues at inception, issues during execution, and exogenous factors.

At times, the results might differ from what might have been expected from the WSARA taxonomy. For example, the ATIRCM B-Kit had a stringent weight requirement to allow its installation on almost all Army helicopters. The procurement quantity cut became inevitable as the design weight exceeded the requirement, leaving CH-47 as the only helicopter capable of carrying it. Hence, the ATIRCM B-Kit cuts were not exogenous, and the root cause was judged to be an unrealistic performance expectation at program inception. Similarly, when the Apache Block III program rejected a higher DoD estimate in favor of a lower service estimate at MS B, the acquisition decision maker adopted an unrealistic estimate, a case for lack of acquisition rigor, not an unrealistic cost estimate.

Upon completion of the alignment process, IDA assessed the results for commonality in root cause across the programs in the survey, where commonality of root

[2] For example, the RAND RCA for the WGS program identified and apportioned cost growth among three independent root causes: (1) the additional four Block II and IIf satellites (29 percent of cost growth); (2) movement of the commercial industrial base from obsolete WGS-compatible technology (26 percent); and (3) an estimating error wherein Block I and II satellites were budgeted at their targeted (rather than ceiling) contract price while additional Block IIf satellites were budgeted at their ceiling (not targeted) contract prices, resulting in an artificial 15 percent growth in unit costs (30 percent). In IDA's evaluation of root cause, all three rose to the level of significance and all three were aligned with the proposed taxonomy.

cause was assessed primarily at the top two levels. Due to the diversity of the programs, specific causal subcategories are likely to vary substantially from program to program. Where commonality is present at the lower level, it may indicate a specific recurrent failure that deserves further investigation. Moving up a level, commonality among the middle tier causes may indicate general shortcomings in the acquisition process, such as requirements determination and acquisition strategy, cost and schedule estimation, or program and contract management. Finally, the distribution of root causes before and during program execution measures the balance between birth defects and bad parenting and indicates the extent to which there are opportunities for remediation within troubled programs.

D. Limitations

In Appendix A, IDA compiled Table A-1 to record the root causes reported in the IDA and RAND RCAs on fifteen programs at the lowest tiers. The practice of assigning root cause based solely on the RCAs allows IDA to remain an objective observer but imposes on IDA's analysis the same limitations that are present in the RCAs. Three prominent shortcomings in the collection of RCAs may limit the generalizability of the results to the broader MDAP portfolio: (1) the stock of RCA programs is small, and the programs are not completely representative of the population of MDAPs and MAIS programs; (2) some of the root causes are interrelated and not independent; and (3) the root causes selection process varies across each of the RCAs. Due to these limitations, the table should be used only for observation, not for generalization.

The survey covers fifteen programs with RCA reports: GCSS-MC, ECSS, and Navy ERP are MAIS programs, while the other twelve are MDAP programs. Currently there are forty-one active MAIS programs and, eighty-one active MDAPs. Consequently, these fifteen programs represent only a fraction of MAISs and MDAPs. Furthermore, all of the programs included in this report either experienced or anticipate a critical Nunn-McCurdy breach. The majority of MDAPs and MAIS programs outside of this report will not experience such extreme cost growth. The results presented here should not be extended to programs with more "normal" cost growth.

The survey table displays the root causes that are ostensibly independent of each other. This layout does not account for the complex interrelationships and interactions among reported root causes. For example, an unrealistically low MS B cost estimate could be caused by an unrealistic schedule or bv unrecognized technology requirements and complexity. An unrealistic schedule could result from a combination of optimistic design maturity assumptions, ambitious requirements, inadequate risk allowance, or a compressed schedule by direction. Ineffective management of contractor incentives could be the result of numerous contract modifications to accommodate changes in requirements and scope. Depending on where the analysis stops along the causal chain of

cost growth, a root cause identified by one analyst may very well be judged as only a proximate cause in passage by another evaluator. The ultimate entry of a root cause at the subcategory level of the above taxonomy represents the individual RCA choice, with little consistency or uniformity. Even at the higher level, reported root causes are not completely independent. Cost growth that generates affordability concerns could induce cuts in procurement quantities and further growth in unit cost (and possibly more quantity reductions). Unanticipated design issues during execution could have their origin in immature technology at the program inception. Root causes of cost growth are so innately intertwined, at this point, we do not have a way to construct an RCA taxonomy totally free of interdependency among the entries. This paper made no attempt to dive further into causes than what has been reported in the RCAs so as to remain objective in the survey.

Finally, the ability to generalize from our results is limited by variations in the root cause selection process across the RCA reports. The RCAs were performed by analyst teams in IDA and RAND. Each team followed PARCA's general guidance to collect program histories, locate proximate causes of cost growth, and determine the root causes of cost growth. The RCAs, however, are noticeably different in the breadth and depth of their analyses and in their selection of root causes. The differences are not just between RAND and IDA, but among RCAs within RAND and IDA performed by separate teams of analysts.

The DDG 1000, WGS, and Excalibur RCAs indicated one or two root causes—quantity reduction and/or unrealistic cost estimate. The Global Hawk RCA identified many—unexecutable schedule, missing program content, and unrealistic cost estimate were defects at the inception of the program; failures of contractor execution, program management, and Air Force oversight and funding approach are shortcomings during program execution. The Remote Minehunting System RCA found, in addition to the commonly cited quantity reduction and unrealistic baseline estimate causes, the failure of government oversight manifested in the system's reliability issues to be a significant root cause of program cost growth.

Both IDA and RAND were commissioned to conduct RCAs on the F-35. The research reached similar conclusions, but the rationales behind that conclusion were quite different. IDA attributed the cost growth to the unrealistic MS B cost estimate associated with the underestimation of airframe unit weight and other errors. RAND found that the root cause lay in an overly optimistic baseline estimate influenced by acquisition reform and produceability initiatives. Both reports identified redesign as a major cause of F-35 cost growth, but could not offer any clear or compelling account of its root causes. IDA suggested that the initial low airframe weight estimate was an issue. RAND associated the extra cost for redesign to the engineering strategy of prototyping Conventional Take-off and Landing (CTOL) first rather than Short Take-off and Vertical Landing (STOVL)

during system design and development. The fact that two independent reports reached somewhat divergent accounts of the causes of cost growth for a single program casts doubt on the consistency of the root cause selection process across different programs and reports.

E. Results

Table 3, Table 4, and Figure 1 through Figure 4 present the results of IDA's assessment of the significant root causes of cost growth across the IDA and RAND RCA reports (Table 1) done for PARCA.

At the top level (Table 3 and Figure 1), root causes are spread relatively evenly between issues at inception, issues during execution, and exogenous factors, with each category contributing roughly 30 percent of the total causal count. Beneath the top level, flawed MS II cost estimates (twelve programs), exogenous directed changes (nine programs), and lack of acquisition rigor (eight programs) during execution stand out from other general causes, with each category represented in more than half of the programs in the sample.[3] IDA grouped all instances where MS B decisions were made without rigorous deliberation on contract strategy, requirements, design maturity, acquisition plan, or cost estimate into the "lack of acquisition rigor" category. Twelve of the programs surveyed reported at least two of these prominent mid-tier causes. Global Hawk, CHEM DEMIL-ACWA, and Apache LB-Blk3 reported all three causes. Evolving requirements and scope (five programs), inadequate government management (six programs) and unanticipated design issue (six programs) were middle tier issues cited for a third of these programs. At the most specific level (Table A-1 and Figure 2), unrealistic development and testing schedule (six programs) and unrecognized technology requirement/complexity (six programs) are the most common causes.

[3] Table A-1 in Appendix A provides a more detailed version of Table 3. This table details assignment of mid- and low-tier causes to the fifteen programs and provides the basis for the results presented in Figure 1 through Figure 4.

Table 3. Root Cause Analyses Summary

Causes of Cost and Schedule Growth	GCSS-MC	ECSS	Navy ERP	ACWA	ATIRCM	CMWS	Global Hawk	F35 (JSF)	RMS	FAB-T	Apache LB-BkIII	DDG 1000	WGS	Excalibur	JTRS GMR	Programs w/Issues
Issues at Inception	●	●		●	●	●	●	●	●	●	●	●	●	●	●	**14**
Unrealistic Performance Expectation					✓	✓									✓	3
Immature Technology					✓	✓					✓				✓	4
Lack of Acquisition Rigor	✓	✓		✓			✓	✓			✓	✓			✓	8
Flawed Milestone II Cost Estimate	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		12
Issues During Execution	●	●		●	●	●	●	●	●	●	●				●	**11**
Unanticipated Design Issues	✓				✓	✓	✓	✓			✓					6
Fragmented and Diffused Management Structure	✓	✓														2
Evolving Requirements and Scope	✓			✓			✓			✓					✓	5
Poor Contractor Performance	✓						✓			✓						3
Inadequate Government Management	✓			✓			✓	✓	✓	✓						6
Exogenous Factors				●			●		●	●	●	●	●	●	●	**9**
Directed Changes/Priorities/ Quantities				✓			✓		✓	✓	✓	✓	✓	✓	✓	9
Constricted Environment to Control Cost				✓												1
Shrinking Business Base/ Emerging Competitor													✓		✓	2
Inadequate Program Funding							✓									1

● Program has at least one mid-tier issue within the top tier

✓ Middle tier issue reported in IDA and RAND RCAs

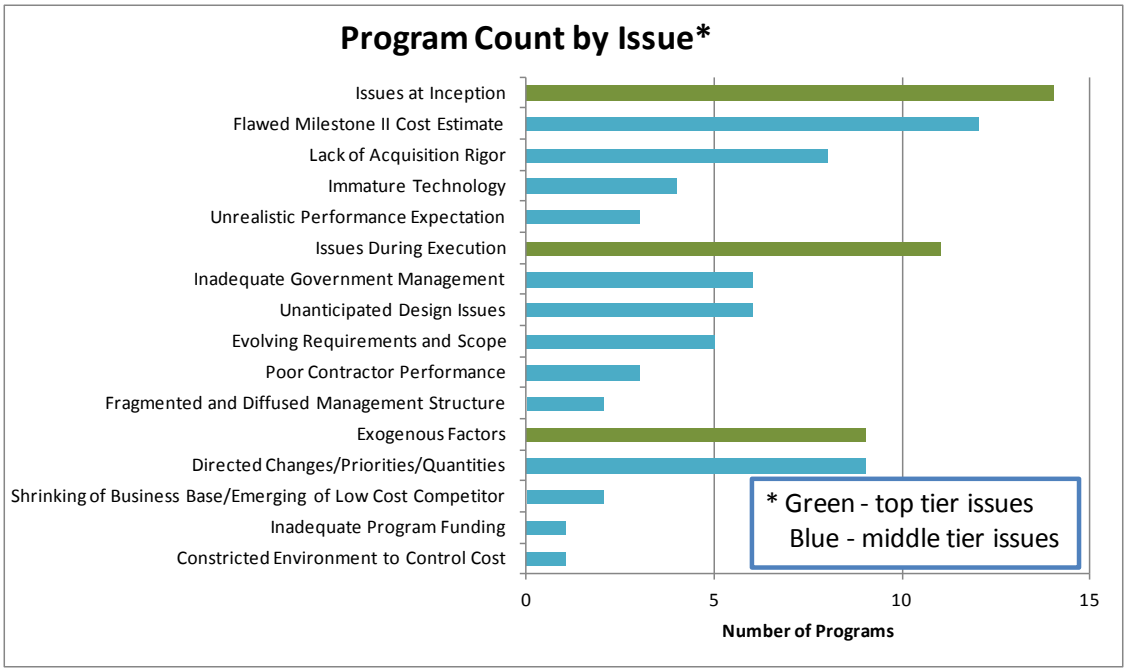


Figure 1. Program Count with Top and Middle Tier Issues

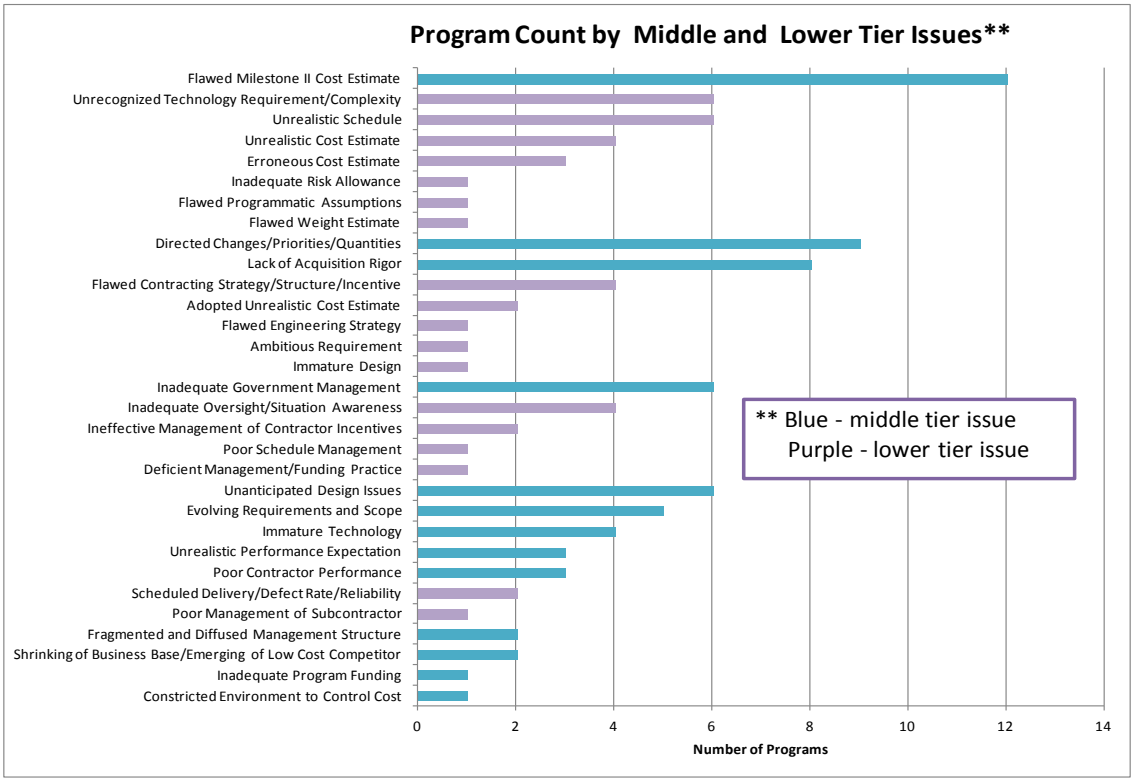


Figure 2. Program Count with Middle and Lower Tier Issues

The number of specific root causes per program varies substantially across the sample shown in Table 4. Navy ERP has no issues, DDG 1000 and Excalibur have two

each, and Global Hawk has eight root causes responsible for its Nunn-McCurdy breach. (See Table A-1 in Appendix A for the assignment of lower-tier root causes to the fifteen programs.) Interestingly, the number of root causes per program does not appear to be related to the degree of cost growth for that program (Figure 3 and Figure 4). The two programs with the highest unit cost growth—ATIRCM and Excalibur—have four or fewer significant root causes of cost growth each, and the program with the greatest number of root causes (Global Hawk) has the least PAUC and second least APUC growth of those surveyed.

Table 4. Middle Tier Issue Counts by Program

	GCSS-MC	ECSS	Navy ERP	ACWA	ATIRCM	CMWS	Global Hawk	F35 (JSF)	RMS	FAB-T	Apache LB-BkIII	DDG 1000	WGS	Excalibur	JTRS GMR
Issues at Inception *	2	1		2	3	3	2	2	1	1	3	1	1	1	3
Issues During Execution Issues*	5	1		2	1	1	4	2	1	3	1				1
Exogenous Factors*				2			2		1	1	1	1	2	1	2
Total Issues	**7**	**2**	**0**	**6**	**4**	**4**	**8**	**4**	**3**	**5**	**5**	**2**	**3**	**2**	**6**
APUC Cost Growth % **				39%	282%	32%	23%	57%	55%	7%	31%	25%	27%	159%	45%
PAUC Cost Growth %**				43%	291%	25%	14%	57%	80%	25%	26%	86%	18%	211%	136%
Growth over MS A Estimate	641%	73%	28%												

* Top Tier issue reported in IDA and RAND RCAs

** Average Procurement Unit Cost (APUC) and Program Acquisition Unit Cost (PAUC) growths measured against program's current baseline

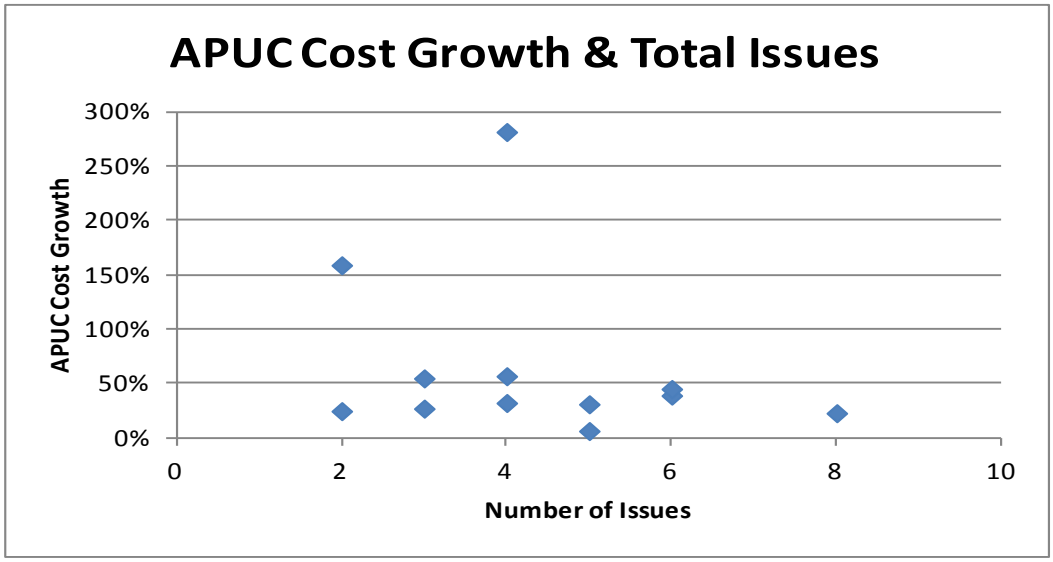


Figure 3. Issue Count by Program and APUC Cost Growth

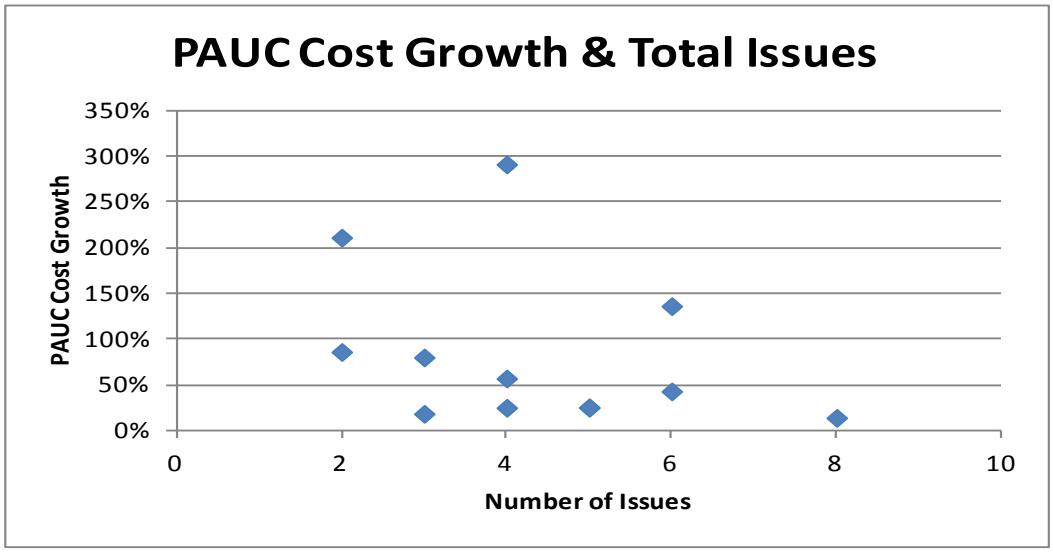


Figure 4. Issue Count by Program and PAUC Cost Growth

A flawed MS II cost estimate is the most prevalent mid-tier cause, cited for twelve programs. Unrealistic schedule and unrecognized technology requirement/ complexity are the top specific root causes in this category. The more detailed Table A-1 shows a great deal of overlap between these two causes and the unanticipated design issue (mid-tier) during execution: seven programs have traced the cost growth to at least two of these causes. These three issues are themselves closely related, as unrecognized technology complexity often leads to schedule delay and unanticipated design issues, which cause additional delays.

Evolving requirements and scope, and inadequate government management, are mid-tier root causes shared by many programs. Changes in program requirements and scope implemented through numerous contract modifications added a substantial amount to the program cost. Inadequate government oversight and ineffective contract management failed to incentive contractors to control cost and produce a quality product on schedule. These are managerial issues during execution with opportunity for correction and improvement. They deserve further investigation.

Directed quantity reduction is the most cited exogenous cause of cost growth. Some programs in the RCA reports have their procurement quantity reduced by half or more. Quantity reduction drives up PAUC, as a program's acquisition cost is amortized over a smaller base.

F. Conclusions

IDA was commissioned to locate common issues in and remedies for the root causes of cost growth across fifteen RCA reports for MDAPs and MAIS programs. Notwithstanding the limitations described in Section D, five specific conclusions can be drawn from this exercise. First, the survey shows that the root causes of a program's cost growth are many. The reported root causes vary from program to program and are often interrelated. Most programs have more than one significant root cause. These observations from the RCA reports stand in contrast to "single cause" theories, which blame extreme cost growth across the MDAP portfolio primarily upon a single factor such as immature technologies, inadequate systems engineering, or acquisition "culture" at DoD. Although some factors—like schedule underestimation, quantity reductions, requirements changes, and ineffective management—are common to several programs, none are present in more than two-thirds of the RCA reports. Furthermore, these factors were never the sole source of cost growth identified for the program in question. Even conceding the limitations of the RCA reports themselves, it is clear that the causes of extreme cost growth are many, not one.

Second, from the prevalence of causes of cost growth at program inception in the RCA reports, we can conclude that the rigor of the MS B process is important for controlling extreme cost growth. Fourteen of fifteen RCA programs identified issues at inception as causes of cost growth. Unrealistic cost and schedule estimates, and flawed contract and contract incentive structure have been cited in several RCAs. Once embedded, issues at inception are difficult to overcome. In the cases analyzed, programs were often directed to re-baseline their estimates or change their contract structure at program restructure to contain future cost growth. A more rigorous and accountable MS B process would help to limit the incidence of birth defects that lead to extreme cost growth in MDAPs.

Third, exogenous factors often contribute to cases of extreme cost growth. Nearly two-thirds of the RCA reports (nine of fifteen programs) cited exogenous quantity reductions, requirements changes, or factors in the acquisition environment as responsible for cost growth. Directed quantity reduction drives up PAUC as a program's acquisition cost is amortized over a smaller number of units. Requirements changes and scope expansions lead to numerous contract modifications and increase the program acquisition cost. To the extent that these factors are truly exogenous to program initiation and execution, their influence on cost growth has the effect of exaggerating the severity of MDAP performance shortcomings in the data. Measures to control requirements growth and acknowledge the costs of directed changes could be implemented at program restructure to manage the influence of such exogenous factors.

Fourth, the RCA reports suggest that proper management of MDAPs is important for controlling extreme cost growth. Roughly half (eight of fifteen programs) of the RCAs reported inadequate government oversight, ineffective contract management, or diffuse management structures during execution as significant causes of cost growth. In some cases during program execution, the government overlooked reliability and contractor performance issues and pressed on with additional contract awards to adhere to an unrealistic schedule. In other cases, such as FAB-T and ECSS, the RCA reported that the government has performed poorly because the program office was understaffed, lacked expertise, and the program manager tenure was short.

Causes at program inception and exogenous factors can be unambiguously associated with given amounts of cost growth, and poor management and oversight issues act to exacerbate the consequences of cost growth, and the tie is difficult to quantify. Nevertheless, these execution issues are even more important to be specified, because they are areas for improvement and remedial actions.

Finally, this exercise highlights the need for improved root cause taxonomy beyond that already suggested by WSARA and PARCA. Although this report proposes an alternative taxonomy, it does so by allowing the RCA reports, which used WSARA as a guide, to largely determine the structure beneath PARCA's top-tier allocation of issues at inception, issues during execution, and exogenous factors. To improve the consistency, understanding, and usefulness of cross-program root cause analyses, more rigor is needed to structure future root cause taxonomies. A broader selection of programs and participants would serve well in future efforts towards this end. Along with improving the rigor of the MS B process, untangling the role of management performance, and acknowledging the influence of exogenous factors, the development of a cross-program RCA structure stands as a key opportunity for improvement.

Appendix A.
Detailed Root Cause Analyses Summary

Table A-1 is a tabulation of root causes of program cost growth reported in the fourteen IDA and RAND reports. The causes are grouped by issues at inception, issues during execution, and exogenous factors. Entries based on IDA reports are in black, and entries from RAND reports are in red. Mid-tier entries are marked with "✓", and lower tier entries are marked with "x".

Table A-1. Detailed Root Cause Analyses Summary

Causes of Cost and Schedule Growth*	GCSS-MC	ECSS	Navy ERP	ACWA	ATIRCM	CMWS	Global Hawk	F35 (JSF)	RMS	FAB-T	Apache LB-BkIII	DDG 1000	WGS	Excalibur	JTRS GMR
Issues at Inception															
Unrealistic Performance Expectation					✓	✓									✓
Immature Technology					✓	✓					✓				✓
Lack of Acquisition Rigor	✓	✓		✓			✓	✓			✓	✓			✓
Flawed Contracting Strategy/Structure/Incentive	×	×		×			×								
Flawed Engineering Strategy								×							
Immature Design				×											
Adopted Unrealistic Estimate											×	×			
Ambitious Requirement															×
Flawed Milestone II Cost Estimate	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
Unrealistic Schedule		×			×	×	×	×		×					
Unrecognized Technology Requirement/Complexity	×	×			×	×		×		×					
Erroneous Cost Estimate				×					×				×		
Unrealistic Cost Estimate		×						×			×			×	
Flawed Weight Estimate								×							
Flawed Programmatic Assumptions								×							
Inadequate Risk Allowance				×											
Issues During Execution															
Unanticipated Design Issues	✓				✓	✓	✓	✓			✓				
Fragmented and Diffused Management Structure	✓	✓													
Evolving Requirements and Scope	✓			✓			✓			✓					✓
Poor Contractor Performance	✓						✓			✓					
Scheduled Delivery/Defect Rate/Reliability							×			×					
Poor Management of Subcontractor										×					
Inadequate Government Management	✓			✓			✓	✓	✓	✓					
Inadequate Oversight/Situation Awareness	×						×	×	×	×					
Deficient Management/Funding Practice							×								
Poor Schedule Management										×					
Ineffective Management of Contractor Incentives				×			×								
Exogenous Factors															
Directed Changes/Priorities/Quantities				✓			✓		✓	✓	✓	✓	✓	✓	✓
Constricted Environment to Control Cost				✓											
Shrinking Business Base/Emerging of Low Cost Competitor													✓		✓
Inadequate Program Funding							✓								
APUC Cost Growth %				39%	282%	32%	23%	57%	55%	7%	31%	25%	27%	159%	45%
PAUC Cost Growth %				43%	291%	25%	14%	57%	80%	25%	26%	86%	18%	211%	136%
Growth over MS A Estimate	641%	73%	28%												

✓ Middle-tier issue
IDA's findings in **black**

× Lower-tier issue
RAND's findings in **red**

Illustrations

Figures

Tables

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Abbreviations

ACWA	Chemical Demilitarization – Assembled Chemical Weapon Alternatives
APB	Acquisition Program Baseline
APUC	Average Procurement Unit Cost
ATIRCM/CMWS	Advanced Threat Infrared Counter Measure/Common Missile Warning System
CHEM DEMIL-ACWA	Chemical Demilitarization-Advanced ChemicalWeapons Alternatives
CTOL	Conventional Take-off and Landing
DoD	Department of Defense
ECSS	Expeditionary Combat Support System
EMD	Engineering and Manufacturing Development
ERP	Enterprise Resource Planning
FAB-T	Family of Advanced Beyond Line-of-Sight Terminals
GCSS-MC	Global Combat Support System – Marine Corps
Global Hawk	RQ-4A/B UAS Global Hawk
IDA	Institute for Defense Analyses
JSF	Joint Strike Fighter
JTRS GMR	Joint Tactical Radio System Ground Mobile Radar
MAIS	Major Automated Information System
MDAP	Major Defense Acquisition Program
MS	Milestone
PARCA	Performance Assessments and Root Cause Analyses
PAUC	Program Acquisition Unit Cost
RCA	Root Cause Analysis
RMS	Remote Mine-Hunting System
STOVL	Short Take-off and Vertical Landing
WGS	Wideband Global Satellite
WSARA	Weapon Systems Acquisition Reform Act
U.S.C.	United States Code

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14. ABSTRACT

The Weapon Systems Acquisition Reform Act of 2009 (WSARA) requires root cause analyses (RCA) be conducted on major defense acquisition programs (MDAPs) with extreme cost growth for its Nunn-McCurdy breach certification process. In 2010 and 2011, the Director for Performance Assessments and Root Cause Analyses (PARCA) conducted fourteen RCAs with support from the Institute for Defense Analyses (IDA), the RAND Corporation, and the University of Tennessee. IDA was tasked to identify common causes exposed by these RCAs. IDA developed a taxonomy to classify the root causes reported by IDA and RAND, compiled a survey table, and identified unrealistic schedule, evolving requirements, inadequate government management, and exogenous quantity changes as the most frequently cited root causes. The survey shows that the root causes of program cost growth are many, not just a "single factor" such as immature technology or lack of systems engineering. The prevalence of causes at program inception shows that a rigorous Milestone B process is important for controlling extreme cost growth. Finally, this report concludes that management of MDAPs matters, as almost half of the RCAs reported inadequate government management as a significant root cause for cost growth.

15. SUBJECT TERMS

Nunn-McCurdy Breach, Root Cause Analyses, Program Acquisition Unit Cost (PAUC), Average Procurement Unit Cost (APUC), Cost Growth, Schedule Delay, Requirements, Quantity, Government Management

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